
INTERAGENCY MEMORANDUM

TO: IOWA DEPARTMENT OF NATURAL RESOURCES
IOWA UST FUND BOARD
IOWA DEPARTMENT OF PUBLIC HEALTH

FROM: PLASTIC WATER LINE RESEARCH COMMITTEE

SUBJECT: SUMMARY OF RESULTS OF LITERATURE REVIEW OF PLASTIC WATER LINES

DATE: 12/19/08

BACKGROUND

The Plastic Water Line Research Committee was formed at the request of the Assistant Director of the Department of Natural Resources and the Chairperson of the UST Petroleum Fund Board to look into the current information available regarding risk to plastic water lines, to summarize key findings, and to make initial recommendations based on the available information.

The Committee was a multi-faceted group comprised of the following members:

- Rochelle Cardinale, Iowa Department of Natural Resources, Underground Storage Tank Section
- James Gastineau, Aon Risk Services, Administrator's Office, Iowa UST Fund Board
- Roy Ney, Iowa Department of Natural Resources, Water Supply Engineering Section
- Stuart Schmitz, Iowa Department of Public Health

Based on our review of the available information, data and reported field occurrences are limited or rarely studied. Nonetheless, there are reports indicating permeation incidents and other impacts have occurred. A survey of states was completed by the Iowa Department of Natural Resources in 2007 requesting information on how plastic water lines are addressed in their respective states. Of the 25 states surveyed, 13 had indicated known impacts to plastic water lines. A number of laboratory studies have been conducted on pipe exposure to petroleum; however, these have been limited in duration to periods of a few years, while water lines may remain in the ground for decades. While many laboratory studies on the impact of petroleum to plastic water lines have been conducted since the 1970's, no national consensus standard has been created or adopted on what constitutes a risk to plastic water lines or other water lines. However, the Ten States Standard is a generally-accepted practice for new line installations and does present recommendations on installation of lines in contaminated areas. The available data, however, suggest plastic pipe and some of the other pipe materials used for water distribution systems may be subject to permeation from organic compounds, such as petroleum, solvents, and other industrial products. Our review of the available data found the following:

KEY FINDINGS

1. PE/PB pipe is prone to permeation from even low levels of contamination.^{1,24} Chemicals can permeate polybutylene (PB) pipes at below their aqueous solubility.² Gasoline compositions such as benzene, toluene, ethylbenzene, and total xylenes (BTEX) appear highly permeable to PB pipe, and vapors as well as aqueous solutions of solvents can permeate PB pipe.² Polyethylene (PE) can be permeated by natural gas odorants.³ There is strong literature and research evidence for a likely exceedance of the health standards for benzene in drinking water as a result of permeation through PE and PB pipes.²⁴ Research indicates that the time of breakthrough of contaminants through the pipe can be very fast with PE/PB.⁴ Most organic chemicals do not affect the structural integrity of semi-crystalline rubbery PE and PB pipe, but the chemicals may readily penetrate the walls of the pipes.⁵

NOTE: Current IDNR regulations prohibit the use of PB pipe for water mains and IDPH Health regulations prohibit the use of PB pipe for underground water service lines. There is the potential that PB pipe may have been used prior to these regulations or in areas not monitored by local regulatory agencies. PE pipe, however, is routinely used in smaller and rural communities for service pipe due to its cost and ease of handling and in limited instances in mains in settings such as river crossings.

2. The permeation mechanics differ for the various types of pipes. Permeation characteristics of the amorphous glassy polyvinyl chloride (PVC) polymer differ appreciably from those of the rubbery PB and PE polymers.⁵ Wall thickness may not have as great an effect on PE and PB permeation as it does with PVC.⁵

3. Research studies indicate PVC pipe is more resistant to permeation than PE/PB, but also that PVC is still vulnerable to permeation. References indicate PVC pipe can be permeated in gross soil contamination or under saturated conditions.⁶ Studies have shown that hydrocarbons (particularly aromatic hydrocarbons such as benzene and toluene) and halogenated hydrocarbons can soften, cause swelling, and permeate PVC.⁷ The aromatic hydrocarbons (such as benzene) and other chlorinated liquids are reported to be strong swelling agents for PVC.⁷ Studies indicate that permeation of PVC at low solute activity is so slow as to be practically non-existent⁷; however, some research members have a concern that the length of the studies was not sufficient to say this would be true over the expected life of the pipe.

4. Chemical activity levels play a role in permeation.^{2,5,7,8,9} Activity is a dimensionless quantity whose magnitude is equal to molar concentration in an ideal solution, equal to partial pressure in an ideal gas mixture, and defined as 1 for pure solids or liquids.¹⁰ Higher concentrations of petroleum contamination in soil and groundwater appear to equate to higher activity levels.

5. PVC pipe can be susceptible to brittle failure^{11,12}. Plastic pipe experiences a dramatic decrease in impact strength as the temperature gets colder, and certain plastic pipes may become increasingly brittle. The impact strength is four times less at -10°C (15°F) than at room temperature – or 20°C (68°F).^{11,12} Plasticizers added to the pipe material may reduce this effect.¹¹ AWWA C900 and ASTM 2241 PVC pipe are produced by an extrusion process that elongates the grain of the material matrix, creating this inherent weakness.²¹ If the PVC line is pressurized and is installed below the frost line, brittle failure may not be as big a concern.

6. Synergistic effects of chemicals can enhance the likelihood of permeation. Studies have shown many permeation incidents occurred where more than one chemical was present.⁵ That pesticides and chlorinated organics can mix with petroleum and impact/permeate plastic pipes is

documented by Park et al (1991).² Studies have shown PVC can become more permeable than PE pipe when BTEX and 1,3-dichlorobenzene (a common solvent) are mixed.^{6,28} The addition of a readily permeable organic chemical to a mixture of relatively non-permeable organic chemicals was shown in laboratory experiments to increase the rate of permeation.^{2,3} One of the reported permeation field incidents occurring in Marion County, Iowa, was at a mixed-chemical facility with fertilizer being carried in petroleum.¹³ The PVC line was observed to have swelling part way through the wall, and a fracture through the wall of the pipe.¹³ Whether the chemicals the pipe was exposed to or an inherent weakness in the pipe were the cause of the fracture or permeation is unknown.

7. Studies indicate all types of gaskets used in pipe distribution systems are at risk. Studies indicate that gaskets have a high intrinsic permeability to organic contaminants and, in areas of gross contamination, can be permeated by components associated with petroleum contamination.⁷ Observation of gaskets at the ISU Research Laboratory showed all gaskets exhibited some swelling after exposure to petroleum.²⁴ Long-term exposure to gasoline resulted in all gasket types failing to meet minimum requirements for tensile strength.¹⁴ Nitrile and fluorocarbon gaskets were shown to be less susceptible to permeation than styrene-butadiene-rubber (SBR) gaskets, with fluorocarbon gaskets providing the best protection against permeation.¹⁵ One of the additional effects from petroleum exposure to gaskets presented in studies is that chemicals of concern may leach out of SBR or nitrile gaskets as part of the petroleum deterioration process.¹⁶

The gasket is not always the primary pathway for permeation⁸; however, the impact of permeation may be severe for small-diameter pipes with low flow.¹⁷ Reports indicate that stagnant water in service lines are more at risk than the water in mains owing to several factors, primarily that they do not have as much flow-through for dilution of the permeates.^{17, 27}

8. Significant early permeation through asbestos-cement (A/C) pipe has been documented upon immersion in several liquid organic solvents.^{3,7,18,19,20,21} It appears warranted this type of pipe also be considered in risk assessment to water lines.

9. Where heavy soil contamination occurs, no pipe system should be considered resistant to permeation.⁶

RECOMMENDATIONS

- A Technical Advisory Group should be formed to consider the recommendations and questions from this research review in greater detail. This group could include staff from the IDNR UST Section, Contaminated Sites Section, Water Supply Engineering Section, UST Fund, IDPH, Iowa Section of the American Water Works Association (AWWA), Iowa Rural Water Association, American Council of Engineering Companies (ACEC) of Iowa, Uni-Bell PVC Pipe Association, Ductile Iron Pipe Research Association, and gasket manufacturers' representatives, and other experts in the field, such as the researchers of the ISU Study and engineers from the Madison Group.
- Plastic water lines (and asbestos-cement pipes) do not react the same when exposed to petroleum; the mechanisms of permeation are sufficiently different. The IDNR Tier 1 action levels for exposure to plastic water lines should be revisited. Different Tier 1 levels for different types of plastic pipe as well as different procedures for addressing lines and gaskets may be warranted.
- Wherever possible, installation of water lines should be avoided in areas where non-aqueous phase liquids (NAPLs) or gross soil contamination are present..

- Organic contaminant-resistant gaskets should be used for water pipe systems in areas of contamination. Nitrile gaskets should be used in areas with low solvent activity, and fluorocarbon gaskets should be used in areas with higher levels of solvent activity (regardless of pipe material).
- If there is the potential on a site for contamination from several sources and chemicals in addition to those found in petroleum products, samples should be collected to evaluate the presence and levels of those chemicals to see if the potential for commingling problems warrant pipe removal.
- This memo should be distributed for comments to the members of NEIPWWC (Drinking Water Program and Tanks Program) and to States contacted for the DNR National PWL Survey. Direct input should also be requested from the State of South Dakota and Missouri on their existing and proposed policies.

QUESTIONS/ADDITIONAL RESEARCH

1. What constitutes gross soil contamination and saturated conditions?
2. What role do chemical activities play in the potential for permeation? The levels at which these promote an environment of permeation is worth more exploration. Studies seem to conflict on whether permeation occurs only at higher values, i.e., 0.3, or can occur at levels below 0.10, if given more time of exposure.²² Many of these studies are conducted for only a few years time, when actual exposure to pipes may occur over a much longer period. Softening has reportedly not been observed at an activity level of 0.05 or lower.²² South Dakota's lookup tables appear to use a value lower than 0.1.²³
3. There are many logistical issues surrounding the potential for permeation of gaskets that may need to be considered. Contamination via gaskets doesn't seem to occur as often as one would expect considering their reported susceptibility, so requiring every gasket to be removed and replaced is problematic. The extent to which ductile iron water lines and other types of pipes with gaskets might be impacted is not readily known, because these lines have generally not been explored. It may also be worth reviewing whether water use patterns and cycling of the main water system (loops) should be accounted for in estimating contaminant infiltration.
4. Study Limitations. Studies acknowledge limitations of laboratory experiments in that it can take years for an impact to occur, and a multi-year study in a lab cannot predict all of the potential circumstances.²⁴ This was reaffirmed by Professor Ong, who headed the ISU study, in various communications in 2006.
5. Correlation between predicting permeation and actual exposure. It is difficult to accurately predict the degree of permeation and subsequent contamination of drinking water.³
6. Diffusion Coefficients. Some articles discuss that factoring in diffusion coefficients for organic chemicals through both saturated and unsaturated soils should be considered.²⁵ Soils generally decrease air or water diffusion coefficients by 1 or 2 orders of magnitude.²⁵ Diffusion coefficients through stagnant water are on the order of 10^{-5} .²⁵ This concept is an option for further research.
7. Organic content and the sorption of BTEX in soils. References state the sorption of BTEX by soils decreases the soil-pore-water BTEX concentration and thus decreases the permeation rate of

BTEX.²⁵ These same resources state high organic matter in soil cannot protect pipes from permeation since the soil would reach its maximum adsorption capacity for organic chemicals.^{4,25} Some references state where pipes are to be installed below the water table or where the site is subject to frequent water logging, it is recommended the soil-pore-water be sampled and analyzed.²⁶ References also state that only in cases where neither soil gas nor soil-pore-water samples can be taken should soil samples be collected and analyzed.²⁶ The question of whether soil sampling is the most appropriate method for establishing permeation susceptibility is an option for further investigation.

8. Current regulations. References discuss looking at the Ten States Standards and the Uniform Plumbing Code. Are they sufficient and enforced? This concept is an option for further investigation.

9. Clay Barriers. Resources recommend using clay barriers within the utility corridor before the metal piping connects back to plastic material.²⁰ This concept is an option for further investigation.

10. Vapor Permeation. Several reports and field examples indicate that vapors can permeate pipes.^{1,2,7,21,25} This mode of transport is an option for further investigation.

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<http://www.dnr.mo.gov/env/hwp/docs/introduction.pdf>
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